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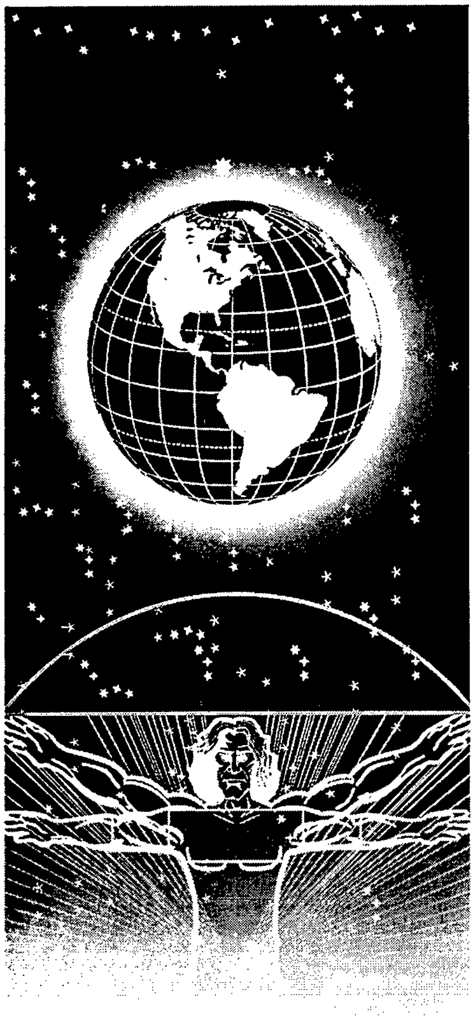

UNITED STATES AIR FORCE RESEARCH LABORATORY

ADVANCED PERSONNEL TESTING PROJECT: FINAL REPORT

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14. ABSTRACT
A new experimental test battery, known as the Advanced Personnel Testing (APT) battery, was investigated in two contexts relating to the Armed Services Vocational Aptitude Battery (ASVAB). Interim results of these investigations are documented in an American Psychological Association Conference paper (first author Goff) and a briefing given to OASD (Sawin). However, the results reported in this paper are based on the full sample collected. Both investigation contexts were large n samples of Air Force basic recruits who took all tests. One context ($n = 9,325$) examined how the best factor structures for the APT and ASVAB tests (modeled separately) were related to each other when assessed in the same latent structure model. Of special interest was a factor (Fact Learning) present in APT but not in ASVAB. A second context involved assessing the incremental validity of APT relative to ASVAB for prediction of technical school grades in a large-flow school (i.e., security police, $n = 2,270$). While the ASVAB predicted technical school grades more strongly than the APT battery, latent structure analyses, on correlations corrected for range-restriction (on the ASVAB), indicated at least some unique prediction of grades by the APT Fact Learning factor ($r = .11$; $z = 4.3$). Standard regression analyses on the same correlations also indicated a significant incremental r ($r = .014$; $F(12,2247) = 10.5$) for APT, with fact-learning and skill-learning tests providing most of the incremental r. This work is legacy work from a closed work unit. There is no active selection research at the Air Force Research Laboratory.

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Advanced Personnel Testing; APT; Armed Services Vocational Aptitude Battery; ASVAB; Cognitive Abilities; Latent-Structure Models of Ability; Personnel Selection

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Preface

The objective of this 6.2 project was to transition tests developed as part of the 6.1 Learning Abilities Measurement Program (LAMP). The work was conducted under Inhouse Work Unit 1123-A1-19, Transition of LAMP Test Technology, however, the project was cut as part of the APOM FY99 budget reduction in the manpower and personnel research areas. This paper documents the Advanced Personnel Testing (APT) program which was designed to enhance Department of Defense (DOD) selection by assessing new tests. Given his overall familiarity with the program (as an outsider) and his technical skills, Mr Scott R. Chaiken was asked to edit documents into a serviceable technical report for this project. While these documents were never intended to be final technical reports, it is his opinion that they provide the best available documentation of what the APT project was and what it found.

The first document in this technical paper (Section 1) is a presentation at the 1997 American Psychological Association (APA) conference by Goff, Sawin, and Earles that compared the factor structure of the APT battery to that of the Armed Services Vocational Aptitude Battery (ASVAB) tests. The other document (Section 2) is a briefing given to the Office of the Assistant Secretary of Defense, Personnel & Readiness, Military Personnel Policy, Accession Policy (OASD (FMP) (MPP) AP). The briefing is a necessary addition to the paper, as the ultimate goal of the APT project was to assess the incremental validity of the APT battery against a final technical school grade with ASVAB already in the prediction equation. That question is only addressed in the briefing.

The APA paper is provided "as-is" except that the original paper references three figures corresponding to an APT model, an ASVAB model, and an APT + ASVAB model. These figures apparently were never completed, however, Mr Chaiken constructed a single figure representing the most complete APT + ASVAB model as a substitute for the three figures (i.e., all models referred to in the APA paper are subsets of the model implied by this figure). The briefing, for which no slide notes were available, is presented in excerpts. Slides pertaining to the origins of the APT battery were removed because this is covered in the paper. He also removed some of the backup slides that seemed to follow a different agenda. The remaining slides address the main results of the APT project--these deal with relative and incremental validity, as well as test fairness.

Both the APA paper and briefing were interim reports given before the data collection was complete. Therefore, Mr Chaiken augmented these documents with results originating from a more complete data set, having processed the data following the procedures of Goff et al., except in two cases. First, he reports results on data corrected for range-restriction, given the prior selection of study participants on the ASVAB (although both corrected and uncorrected data are provided in Section 3 of this technical paper). Second, with regard to EQS models investigated, Mr Chaiken set the variances of all factors to 1.0 and allowed all loadings on factors to be free rather than (as in Goff et al.) fixing one factor loading (i.e., the highest) and allowing the factor variance to be a free parameter. The validity (e.g., significance of the results) he reports would be the same as the Goff et al. representation, which is not an "identifiably" different model.

Sample 1 is the complete sample of Air Force basics who took both APT and ASVAB tests (n = 2,270), which contains all tests plus a final technical school grade for the security police specialty. Sample 2 is most relevant to the briefing. The range-corrected, or disattenuated, covariance data for these samples are provided in the context of an EQS specification for the most inclusive model reported in Goff et al. In general, parameter estimates and fits reported in the paper are very similar to the model fit to the full sample (allowing for the expected effects of range correction). Sample 2's model is the same as in Goff etal. but adds one variable to the system of equations, namely, the final grade on all the factors present in the ASVAB and APT. In addition, Mr Chaiken used SPSS to address standard incremental validity questions (by analyzing Sample 2's corrected matrix). The results given in the (overall) abstract are derived from these analyses of Sample 2.

Some results discussed in the briefing but not addressed in Mr Chaiken's archival tables (i.e., issues of test fairness) could be addressable in the anonymous subject-level database that generated the tables. A text-based version of this subject-level database can be made available for academic purposes. Unfortunately, data pertaining to schools other than security police, as reported in the briefing, were not archived, though the results reported in the briefing concerning the other schools appear similar to what was found with the security police.

Section 1

The Factor Structure of Two Abilities Tests:
APT vs. ASVAB

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Abstract

The latent variable structure of the Armed Services Vocational Aptitude Battery (ASVAB), a traditional, paper-and-pencil, multiple-aptitude battery, and the Advanced Personnel Testing Battery (APT), a computer administered cognitive abilities battery, were examined separately and together. As anticipated, the structure of the ASVAB included on General factor and three or four specific factors depending on the model tested. The latent variable structure of the APT conformed to expectations, and included a General factor and three orthogonal, specific factors. Results of the joint analyses revealed that incorporating tests that measure fluid intelligence, spatial ability, and fact learning into the ASVAB should increase or improve the abilities measured by that instrument.

Introduction

Multiple aptitude test batteries continue to be of interest to many institutions for employee placement and selection purposes, including government agencies (Schmitt, Sackett, & Cascio, 1996 and Hedge, Cartyer, Borman, Morgan, & Foley, 1993) and private businesses (Hough-Dunette & Tippins, 1994). A potentially new direction in individual aptitude testing has been derived from cognitive psychology which provides the theory behind measurement of an examinee's information processing capacity instead of the more traditional assessment of one's knowledge base (Anderson, 1983, Gustafsson and Muthen, 1994; Kyllonen, 1993; Kyllonen, 1994; Kyllonen & Alluisi, 1987, Kyllonen and Christal, 1989).

Within the above context, the Advanced Personnel Testing (APT) tests have been generated and categorized on the basis of a consensus model of information processing. This is a subset of the 59-test CAM4 battery (see Kyllonen, 1994 for a detailed description of the theoretical development of this battery), which supports the two major dimensions of (1) cognitive processes and (2) content domains. The cognitive processes dimension includes six domains: working memory capacity (WM), declarative/fact learning ability (FL), procedural/skill learning ability (SL), breadth of procedural knowledge (Induction; IN), breadth of declarative/general knowledge (GK), and processing speed (PS). Of relevance to present concerns are the four components purported to measure processes that are believed to be potential sources of individual differences in cognitive ability. They have also been related to success in various learning contexts (Kyllonen & Christal, 1989). These components can be defined as follows. Working memory capacity measures the ability to simultaneously store old information and to process new information. Processing speed measures the ability of an individual to retrieve and process known information. Declarative/fact learning taps the ability of the individual to learn new facts, while procedural/skill learning measures the ability of the individual to learn simple, novel rules for classifying facts (Kyllonen, 1993).

The content dimension consists of three domains: verbal, quantitative and spatial. The three content domains are hypothesized to reflect individual differences in relative knowledge (e.g., verbal vs. quantitative). In turn, these domains are postulated to be independent of general differences in declarative or procedural knowledge (Kyllonen, 1994). Only tests representing working memory capacity, declarative/fact learning, procedural/skill learning, and induction (which tests the breadth of procedural knowledge) are examined in this study, although all

three cognitive domains are represented. This gives us a four by three matrix generating the 12 tests employed in the present investigation.

This study examines the factor structure of the computer-administered APT battery which is in the process of being validated. The structure of the Armed Services Vocational Aptitude Battery (ASVAB) , a traditional, multiple-choice format, multiple-aptitude battery used by all the services to select and classify enlisted personnel (Department of Defense, 1984), is also presented. In addition, the APT battery was factored in the 'presence' of the ASVAB.

For the APT Battery a nested factor model (which hypothesizes one general factor and some number of orthogonal specific factors) is assumed. Specific factors for Fact Learning, Skill Learning, Induction, Working Memory, Quantitative, Spatial, and Verbal are investigated as this is part of the cognitive theory behind the taxonomy underlying the test design. It is hypothesized that the factor for Working Memory will be indistinguishable from the General factor (Kyllonen, 1993, 1994). Previous confirmatory factor analyses of the current version of the ASVAB subtests have reported a four factor structure consisting of Verbal, Speed, Technical, and Quantitative factors (Ree & Carretta, 1994; Ree & Earles, 1990; Ree et al., 1982).

Previous studies have also shown that enhancing the ASVAB battery with tests measuring working memory, reasoning, and spatial visualization produce a model that can include both General Intelligence - G, and Crystallized Intelligence - Gc factors, a Broad Visualization (Gv) or Spatial factor, a Speed factor, and a Quantitative factor (Gustafsson & Muthen, 1994; Sterling, Goff, & Sawin, 1997). Theoretically, the present study assumes that our combined ASVAB-APT data set has a very similar structure, although it might also include some of the specific factors hypothesized in the APT analyses.

Method

Participants

Participants were 6608 Air Force enlistees tested during their final (sixth) week of basic training. They were considered representative of USAF enlisted personnel at that point of basic training. Data was gathered between March 1994 and July 1995. Testing was conducted in mixed sex groups of no more than 40. Before administering the battery the test proctor informed all individuals that their participation was voluntary. Participants were also assured that, in accordance with the Privacy Act, all information they provided would be strictly confidential.

Although the complete sample size was 7088, not all recruits finished every test; 6669 recruits had complete data on all 12 of the APT subtests administered in the first set and also had valid data on the AFQT composite. Because participation was voluntary, we adopted the decision rule to exclude individuals who appeared to have under-performed on the focal set of 12 APT tests given their AFQT scores. We operationalized this rule by regressing total scores (correct/incorrect) for each the 12 focal APT tests on AFQT scores and then computing standardized residual scores. Unmotivated participants were identified as those who obtained (across the 12 subtests) 3 or more standardized residuals (*z*-scores) that were less than or equal to -3.0. Using this procedure we identified 61 participants who appeared to be non-motivated performers. Accordingly, we eliminated these individuals from the data set, leaving an effective sample size of 6608. Of the 6608 participants, 5367 (81.2%) were males and 1241 (18.8%) were female. With respect to race/ethnicity, 4988 (75.5%) of the recruits were Caucasian, 886 (13.4%) were African American, 378 (5.7%) were Hispanic, 152 (2.3%) were Asian, 61 (.9%) were Native American, and 143 (2.2%) responded they were Other. The modal age of participants was 18 (32%). Sixty-one percent of subjects had completed their high school education, while 33% had completed some college hours. Examinees had an average AFQT percentile score of 67.

One concern with this data is that the recruits represent a selective sample compared to the entire population who take the ASVAB. This can lead to problems due to range restriction, such as lower correlations between measures in the restricted sample compared to the unrestricted population. Using the correlation matrix, means, and standard deviations from the ASVAB 1980 normative sample (Wegner & Ree, 1984; Bock & Mislevy, 1981), the correlations, means, and standard deviations for the APT battery were corrected for range restriction. Analyses were performed on this data as well as the unrestricted data. Results from the corrected analyses did not differ much from the original analyses, they are presented in Appendix A.

Instruments

Participants were tested on Unisys 386 25 MHz microcomputers with 15" multisync non-interlaced color monitors. The 17 APT subtests were administered in two fixed sets, with a five minute break between sets. There were 12 and 5 subtests in the first and second sets, respectively. Items were administered randomly within each test, and tests were administered randomly within each set with a few constraints on the subtest ordering such as the working memory-spatial and fact learning-spatial tests not being presented consecutively. We will use the

information from the first 12 of the 17 tests administered. The data set also included the ten test scores on the ASVAB Test Battery for each, as well as the usual composite scores. The battery is available in both pencil-and-paper and computer-adaptive (CAT-ASVAB) forms. Scores on both forms are parallel to each other and to the reference form of the ASVAB. The scores used in the present study were taken from the tests administered to each recruit before his/her admittance into the military. Most enlistees were tested using the traditional pencil-and-paper format.

The APT tests are a subset of the CAM4 battery, developed by researchers at the Armstrong Laboratories Human Resource Division by the LAMP team (see Kyllonen, 1994 for a detailed account of the theoretical development of the CAM4 battery). The LAMP tests were generated and categorized on the basis of a taxonomy based on the consensus model of information processing, as well as research which suggests that the content of the test also provides systematic variance in individual test scores. Although the taxonomy is multidimensional, the two major dimensions which drove test development include cognitive processes and content domains. These dimensions give rise to the theoretical model for the APT tests examined in this study.

The cognitive processes dimension includes six domains: capacity of working memory, declarative/fact learning ability, procedural/skill learning ability, breadth of procedural knowledge (Induction), breadth of declarative/general knowledge, and processing speed. The content dimension consists of three domains: verbal, quantitative and spatial. The three content domains are hypothesized to reflect individual differences in relative knowledge (e.g., verbal vs. quantitative) which are independent of the general differences in declarative or procedural knowledge (Kyllonen, 1994). Only tests representing the first four cognitive processes are examined in this study, but all three cognitive domains are represented. This gives us a four by three matrix generating the 12 tests: Working Memory-Quantitative (WMQ), Working Memory Spatial (WMS), Working Memory-Verbal (WMV), Inductive Reasoning-Quantitative (INQ), Inductive Reasoning-Spatial (INS), Inductive Reasoning-Verbal (INV), Fact Learning-Quantitative (FLQ), Fact Learning-Spatial (FLS), Fact Learning-Verbal (FLV), Skill Learning-Quantitative (SLQ), Skill Learning-Spatial (SLS), Skill Learning-Verbal (SLV). The name of each test (e.g., WMQ, working memory quantitative) indicates the cognitive process and content domain being measured. Detailed descriptions of the APT tests used in this study can be found in Appendix B.

The traditional, knowledge-based ASVAB battery consists of: verbal measures of general science (GS), word knowledge (WK), and paragraph comprehension (PC); quantitative measures of arithmetic reasoning (AR) and

math knowledge (MK), and technical measures of auto and shop knowledge (AS), mechanical comprehension (MC), and electronic information (EI). There are also two tests that measure perceptual speed: numerical operations (NO) and coding speed (CS). Appendix C contains descriptions of the ASVAB tests used in this study.

Analyses

A series of confirmatory factor analyses were performed using the STREAMS shell (Gustafsson & Stahl, 1996) which interacts with LISREL 8.12 (Joreskog & Sorbom, 1993, used in this study), as well as EQS (Bentler, 1993). Data for the analyses were the twelve, standardized, percent-correct APT scores. As described above, the analyses include a number of models based on the nested factor model which hypothesizes one general factor and some number of orthogonal specific factors. Specific factors for Fact Learning, Skill Learning, Induction, Working Memory, Quantitative, Spatial, and Verbal are investigated. It was hypothesized that the factor for Working Memory will be indistinguishable from the general factor (Kyllonen, 1993; Kyllonen, 1994), but our original theory assumed that the rest of the specific factors would be found.

A similar set of analyses were done on the ASVAB scores. Three sets of scores were analyzed. The first set was comprised of all ten subtests. Since the services are considering dropping some of the tests in the battery, the second set excluded Numbers and Operations (NO), while the third excluded NO and Coding Speed (CS). For all three subsets a Nested Factors model with three or four constructs was hypothesized: Mathematics, Technical, Verbal, and Speed (where appropriate.)

An additional analysis was performed in order to compare the overlap of the APT and ASVAB. First, the factors from the nested factors approach for both the APT and the ASVAB were correlated. Factor loadings were fixed to the values arrived at in the previous analyses, and the factors were allowed to correlate across the batteries, while remaining uncorrelated within a battery. A slightly different model was investigated which allowed only the General factors from APT and ASVAB to be correlated, while assuming the specific factor variances between the tests were uncorrelated. The third analysis determined the fit of a model comprised of variables from both batteries with one General factor and specific factors corresponding to those found in the previous analyses. Finally, a model was tested that contained a General factor and various specific factors suggested by previous research, which were allowed to contain variables from both batteries.

Results

APT - Nested Factors

Results from the analyses using the nested factors approach on the 12 percent-correct scores are listed in Table 2. Several models with varying numbers of factors were analyzed. The first model posited a General factor underlying all the scores with no other factors necessary. Examination of the fit statistics suggested that while this model may be acceptable, modifications of this very simple structure may provide a better model. The Root Mean Square Error of Approximation (RMSEA) (Brown & Cudeck, 1993; Steiger, 1990) takes into account both the precision of the fit statistic and the population error of approximation. Guidelines for evaluating the RMSEA statistic are that it should fall between .03 and .08, with .05 or lower being the target value. The Goodness of Fit Index (GFI) and the Chi-square statistic are more traditional indices of fit. One looks for values of .95 and above for the GFI. While the Chi-square statistic (χ^2) is not as useful for large sample sizes, some researchers look at the χ^2 value divided by (n/1000) when the sample size is much larger than 1000. For a discussion of these and many other fit indices, see Joreskog & Sorbom (1993) and Gustafsson & Stahl (1996). In the current study, the RMSEA was .051 for the one factor model, while the GFI = .97. The χ^2 value (967, degrees of freedom –df = 54) is high even when one takes into account the large sample size of 6608.

Several two factor models, all including a general factor and one specific factor, were fitted to the data as well. The additional factor was one of the following: Working Memory, Skill Learning, Fact Learning, Induction, Quantitative, Spatial, or Verbal. The results indicate that Working Memory, Skill Learning, and Quantitative were indistinguishable, given a general factor. Results do suggest that Fact Learning, Induction, Spatial, and Verbal are present although the Verbal factor is quite weak. Evaluating the improvements in fit, one finds that adding the Spatial factor as a second factor results in the best fitting model. The fit indices for this model were $\chi^2(50) = 544$, RMSEA = .039, and GFI = .99.

For theoretical reasons, models including a general factor and two specific were also examined. Working Memory, Skill Learning, and Quantitative were not examined because they could not be determined previously. Induction, Fact Learning, and Verbal were investigated as additional factors. Results for these models show that both Induction and Fact Learning provided improvements to the fit. At this stage, however, the Verbal factor

disappeared. A final four factor model with General, Spatial, Fact Learning, and Induction showed a slight further improvement in fit.

In order to decide on a final model, theoretical issues as well as parsimony issues arise. Parsimony suggests the simplest model that adequately fits the data is the one to choose, so either a one or two factor model should suffice. Theoretical issues suggest that all four factors are necessary as the factor variances are all significant and the specific factors were all posited from the beginning of the study. The results from this model are presented in Table 3.

ASVAB - Nested Factors

The results for the ASVAB nested factors models can be seen in Tables 4 through 8. The results from the complete battery are presented in Tables 4 and 5. Table 6 presents data from the set that does not contain Numbers and Operations (NO). Finally, Tables 7 and 8 present the results from the various models for the 8 variable subset (no NO and no Coding Speed - CS). For all sets of data we found a General factor plus three or four specific factors: Verbal, Math, Technical, and Speed (in the first two sets). While Verbal loaded on GS, WK, and PC for the first models, if one pursues a best fitting model, the results show that GS does not load on Verbal. Theoretical and goodness-of-fit issues suggest that the models with Verbal loading on GS, Technical loading on GS and AR, and with Speed loading on PC, AR, and MK are preferable, so subsequent analyses used one of those models. For the 10 variable data, we used a model with General Intelligence (all variables), Quantitative (AR, MK, and NO), Technical (AS, MC, EI, GS, and AR), and Speed (NO, CS, PC, AR, and MK; see Table 5 for these results). For the 8 variable data set (Table 8), Quantitative has only AR and MK; Technical has AS, MC, EI, GS, and AR; and Speed is not included. Further analyses were not performed with the 9 variable subset, but it should be noted that including the Speed factor improved the fit greatly.

ASVAB & APT Analyses

Table 9 presents the correlations between factors from the nested models for the APT and the ASVAB test batteries. The first matrix of correlations represents the 10 variable ASVAB subset data, while the second matrix represents the 8 variable data subset. Both correlation matrices show that the APT General factor correlates most highly with the ASVAB General and Quantitative factors and has low correlations with the other two or three ASVAB factors, Verbal, Technical, and Speed. The Fact Learning factor has small negative correlations with General, Technical and Speed, and has a weak positive correlation with Verbal. The correlation with Quantitative is

positive, but non-significant, in one group and zero in the other. Induction has a moderate positive correlation with the ASVAB General factor while all other correlations are low and positive except the correlation with Speed which is low and negative. The APT Spatial factor is positively correlated with the ASVAB General factor. It also has moderate negative correlations with Verbal and Quantitative and a small negative correlation with the ASVAB Speed factor. If one hypothesizes a model that constrains the intercorrelations between the two test batteries to just one correlation between the two General factors, one obtains a correlation of 0.75 for the 10 variable ASVAB set and a correlation of 0.78 for the 8 variable data set.

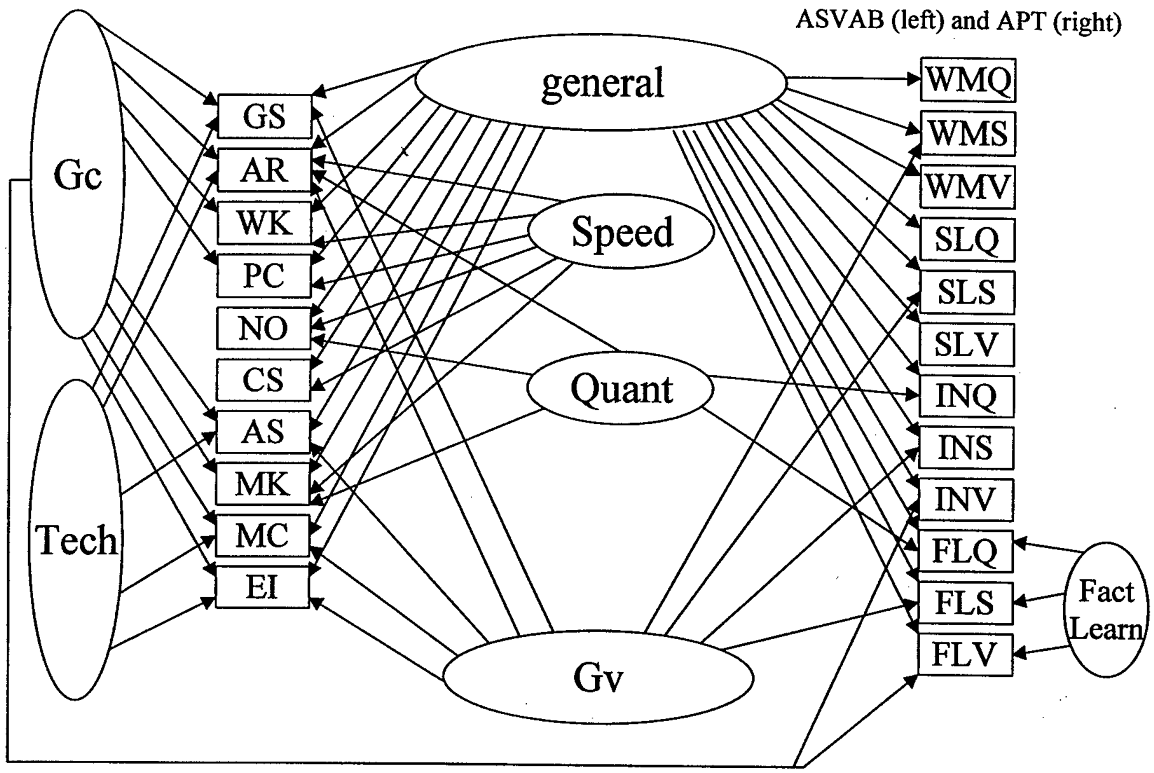
Tables 10 through 13 present the results of analyses on the 22 and 20 (no NO & CS) variables. The models at first hypothesize one General Intelligence factor and then include the specific factors found in the previous analyses as well as the General factor. The fit for the model with one factor was not acceptable for either data set. The RMSEA values were 0.105 and 0.102, while the GFI values were 0.78 and 0.80. Given the larger sets of variables, the Induction factor was not stable. Most analyses that included Induction would not converge without fixing the factor loadings to being equal; while in others, the factor variance was non-significant. Inclusion of this factor also did not improve the fit of the model. While the fit indices for the models comprised of the factors for the separate batteries are not unreasonable, they still show plenty of room for improvement of fit. For both data sets, the RMSEA was somewhat high, but within the accepted range at 0.061 for the 22-variable data set and 0.063 for the 20-variable set. The GFI values were lower than optimal at 0.93 and 0.94, respectively.

The preferred model has a structure which included a General Intelligence factor - G, Crystallized Intelligence - Gc, Broad Visual Perception - Gv, Technical, Speed (NO and CS are included), Quantitative, and Fact Learning factors (see Figure 1). In the final analyses for both sets of variables the tests that loaded on the Technical factor included GS and AR from the ASVAB. For the Quantitative factor, originally AR, MK, and NO (if available), only the appropriate Induction and Fact Learning tests from the APT battery loaded positively and significantly on this factor. The loadings for the FLQ tests were quite small, however, at 0.10 and 0.11 for the 22 or 20 variable data set respectively. The three technical tests (AS, MC, and EI), as well as GS and AR, from the ASVAB battery also loaded on Gv which, as expected, contained all four Spatial content tests from the APT Battery. Crystallized Intelligence included all of the ASVAB tests except NO and CS, as well as FLV and INV from the APT. Note that the loading for FLV was quite small at 0.09 or 0.08, although it was significant. The Fact Learning factor does not change with the inclusion of the ASVAB tests. The three Fact Learning tests are still the only ones

that load on that factor. The next factor is only found in the 22 variable data set. The structure for the Speed factor is similar to the one found in Gustafsson and Muthen (1994), but the loadings for AR, MK, WK, and PC are relatively smaller while CS, with a standardized loading of 0.98, is almost indistinguishable from the factor. The fit indices for this model show a great improvement over the previous models with an RMSEA of 0.037 and a GFI of 0.98 for both sets of variables.

Figure 1

. Model for Table 11:
ASVAB (left) and APT (right)



Discussion

The theory underlying the APT test battery states that there are separate cognitive processes and separate content domains: Working Memory, Skill Learning, Fact Learning, and Induction; and Quantitative, Spatial, and Verbal respectively (Kyllonen, 1993; Kyllonen, 1994; Kyllonen & Alluisi, 1987). Confirmatory Factor Analysis of the available data set support only aspects of this theory. Thus, in all of the analyses performed, Working Memory and Skill Learning are indistinguishable from each other and from General Intelligence. Separate Fact Learning, and Induction factors, however, are found in these analyses. Of the three content factors that were originally theorized, only the Spatial factor is supported in this data set.

One can speculate as to the reason why these analyses do not support the original model. Perhaps the underlying theory is incorrect at least in part, but that conclusion is premature. These data derive from a restricted sample of the population and even correcting for range restriction may not adequately address this problem. The low amount of explained variance for each test suggests that there may be problems with the construction of the test battery. Since there is only one test for each process/content area in this battery (e.g. Induction-Verbal or Working Memory-Spatial), it is impossible to distinguish measurement error and unique test variance so either or both of the next suggestions may be true. The specific test component (e.g. Fact Learning Quantitative) may override any distinguishable Quantitative or Verbal factors. Alternatively, some of the tests may have poor reliability and thus may not have much Verbal or Quantitative variation to contribute to one of those content factors.

The structure of the ASVAB found in this study is quite similar to findings in previous studies. We find a General factor plus three or four specific factors: Verbal, Quantitative, Technical, and Speed (where applicable). While some of the studies have factors which consist of slightly different variable sets, all agree on which variables have high loadings for a factor and thus are theoretically the most important to the factors. For instance, some studies define the Verbal factor to include just Word Knowledge and Paragraph Comprehension, while others also include General Science and/or Electronic Information as well. One should note that the inclusion of GS and AR in the Technical factor found in this study suggests that this factor may include science or technical vocabulary competence or, perhaps, spatial ability.

Unlike the ASVAB analyses, which held no surprises, the findings of the factor correlations and joint analyses of the APT and ASVAB are compelling. The important conclusions from the correlations are as follows. The APT General factor correlates most highly with ASVAB Quantitative and ASVAB General, which suggests that General Intelligence as measured by the APT is related as much to Crystallized Intelligence (Gc) as it is to Fluid Intelligence (Gf). The positive correlation between the APT Spatial and ASVAB General factors and the negative correlations between Spatial and the ASVAB Verbal and Quantitative factors suggest that the ASVAB General factor contains Broad Visualization (Gv) components, and perhaps Gf (or WM), as well as Gc, since Spatial abilities are usually highly correlated with the Fluid Intelligence domain (Carroll, 1993). In light of later findings, it is interesting to note that Spatial does not correlate much with the Technical factor. This suggests that the variance of the tests underlying this factor that is attributable to visual processes is subsumed by the General factor in the

ASVAB battery. Also, the low correlations of Fact Learning with all of the ASVAB factors suggest that this process is not measured at all by the current ASVAB tests.

As mentioned previously, Gustafsson and Muthen (1994) found very similar results when the ASVAB is augmented with other tests that measure domains not well-represented on the ASVAB. Our study did distinguish between Gv and Technical and found a factor for the Fact Learning process as well. Note also that only the appropriate Induction and Fact Learning tests from the APT battery load positively and significantly on the Quantitative factor. This suggests that the tests in this content domain of the APT should be re-evaluated and perhaps revised if they are to reflect the Quantitative content area. Also of interest is that Gc is made up of all ASVAB tests except NO and CS, as well as FLV and INV from the APT battery. One would expect the verbal tests from the APT battery to load on this factor and perhaps also quantitative tests as previous studies have found, although this result was not presently obtained (see Carroll, 1993 for an overview of this area of research). The General factor is weighted towards the working memory and skill learning tests from the APT battery as well as some of the quantitative tests from the ASVAB battery. This finding, coupled with the existence of the Gc and Gv factors in the model, validates the assumption that this General factor may be interpreted as Fluid Intelligence.

Conclusions

In summary, these findings support previous research done in the field of cognitive theory that suggests that G, Gf, and WM are indistinguishable from each other, while Gc and Gv are separate constructs (Gustafsson & Muthen, 1994; Kyllonen & Christal, 1990). This finding, along with research done on the ECAT (Alderton, Wolfe, & Larson, 1997; Wolf, Alderton, Larson, &, Held, 1995) and on other experimental batteries, supports the suggestion of incorporating one or more tests that measure fluid intelligence, working memory, or reasoning into the ASVAB battery. Another important finding is that one can distinguish Gv from the Technical factor in this study. This suggests that the addition of one or two purely spatial tests to the ASVAB battery may be enough to permit a similar finding. The APT battery does provide an additional factor, Fact Learning, that is not found in the ASVAB battery at all. This cognitive domain might also provide some new tests to augment the ASVAB battery.

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Table 1: Means and Standard Deviations

	N=6608	
APT:		
Working Memory		
Quantitative	50.00	10.00
Spatial	50.00	10.00
Verbal	50.00	10.00
Skill learning		
Quantitative	50.01	10.00
Spatial	50.00	10.00
Verbal	50.00	10.00
Induction		
Quantitative	50.00	10.00
Spatial	50.00	10.00
Verbal	50.00	10.00
Fact Learning		
Quantitative	50.00	10.00
Spatial	50.00	10.00
Verbal	50.00	10.00
ASVAB:		
General Science	54.77	6.62
Arithmetic Reasoning	55.09	6.60
Word Knowledge	54.38	4.33
Paragraph Comprehension	54.81	4.60
Auto Shop	51.46	8.20
Math Knowledge	57.40	6.50
Mechanical Comprehension	55.27	8.06
Electronic Information	52.77	7.69

Table 2: APT Battery Structure

Model	Fit Statistics			
	Degrees of Freedom	Chi-Square	RMSEA	GFI
1) General (G)	54	967	.051	.97
2a) G + Spatial (Spat)	50	544	.039	.99
2b) G + Induction (In)	51	903	.050	.98
2c) G + Fact Learning (FL)	51	909	.050	.98
3a) G + Spat and In	47	472	.037	.99
3b) G + Spat and FL	47	425	.035	.99
3b) G + In and FL	48	849	.050	.98
4a) G + Spat, FL, & In	44	362	.033	.99

Table 3: Results from Final APT Model

Includes General Intelligence,
Spatial, Fact Learning, and Induction Factors

Goodness of Fit Tests:
Chi-square = 361.72, df = 44, $p < .00$
RMSEA = .033, p-value for RMSEA < 0.05 = 1.00
Fit Indices: GFI = .99, AGFI = .98, NFI = .98, NNFI = .97, CFI = .98
T-Values for Factor Variances:
General = 24.51
Spatial = 9.69
Fact Learning = 3.99
Induction = 2.53

Standardized estimates:

	General	Spatial	Fact Learning	Induction	Unique Variance
WMQ	0.51				0.74
WMS	0.62	0.32			0.51
WMV	0.56				0.69
SLQ	0.60				0.64
SLS	0.53	0.23			0.66
SLV	0.54				0.71
INQ	0.45			0.19	0.76
INS	0.47	0.19		0.34	0.63
INV	0.44			0.16	0.78
FLQ	0.39		0.24		0.79
FLS	0.57	0.58	0.22		0.30
FLV	0.42		0.30		0.73

Table 4: ASVAB Battery

10 Subtests (include NO & CS)

Model	Fit Statistics			
	Degrees of Freedom	Chi-Square	RMSEA	GFI
1) General (G)	35	7762	.183	.79
2) G + Verbal, Technical, Quant, & Speed	25	1172	.083	.96
3) G + Verbal, Technical, Quant, and modified Speed	21	659	.068	.98
4) G + Verbal, modified Tech, Quant, and modified Speed	19	500	.062	.99
5) G + Verbal, modified Tech, Quant, and modified Speed	18	484	.063	.99

In Model 2: GS, WK, & PC tests make up Verbal factor.
AS, MC, & EI tests make up Technical factor.
AR, NO, & MK tests make up Quantitative factor.
NO & CS make up Speed factor.

In Model 3: add PC, AR, & MK to Speed.

In Model 4: add GS & AR to Technical.

In Model 5: add WK to Speed.

Table 5: Results from Final ASVAB Model

(10 Variables)
Includes General Intelligence,
Technical, Verbal, Quantitative, and Speed Factors

Goodness of Fit Test:

Chi-square = 499.67, df = 19, p < .00

RMSEA = .062, p-value for RMSEA < 0.05 = .00

Fit Indices: GFI = .99, AGFI = .96, NFI = .98, NNFI = .95, CFI = .98

T-values for Factor Variances:

General = 25.06
Verbal = 9.62
Technical = 14.08
Quantitative = 10.49
Speed = 10.37

Standardized estimates:

	General	Verbal	Technical	Quantitative	Speed	Unique Variance
GS	0.67	0.27	0.13			0.46
AR	0.56		0.13	0.49	0.20	0.39
WK	0.51	0.74				0.19
PC	0.39	0.31			0.15	0.73
NO	-0.02			0.22	0.65	0.53
CS	-0.01				0.88	0.23
AS	0.37		0.88			0.09
MK	0.53			0.52	0.21	0.40
MC	0.68		0.36			0.41
EI	0.62		0.41			0.45

Table 6: ASVAB Battery 9 Subtests (includes CS, not NO)

Model	Fit Statistics			
	Degrees of Freedom	Chi-Square	RMSEA	GFI
1) General (G)	27	4792	.163	.84
2) G + Verbal, Technical, and Quant	20	1142	.092	.96
3) G + Verbal, Technical, Quant, and Speed	16	612	.075	.98
4) G + Verbal, modified Tech, Quant, and Speed	14	461	.069	.99
5) G + Verbal, modified Tech, Quant, and modified Speed	13	452	.072	.99

In Model 2: GS, WK, & PC tests make up Verbal factor.
AS, MC, & EI tests make up Technical factor.
AR & MK tests make up Quantitative factor.

In Model 3: CS, PC, AR, & MK make up Speed.

In Model 4: add GS & AR to Tech.

In Model 5: add WK to Speed.

Table 7: ASVAB Battery 8 Subtests (does not include NO & CS)

Model	Fit Statistics			
	Degrees of Freedom	Chi-Square	RMSEA	GFI
1) General (G)	20	4250	.179	.85
2) G + Verbal, Technical, and Quant	14	848	.095	.97
3) G + Verbal, Technical, and Quant	13	609	.083	.98
4) G + Verbal, modified Technical, and Quant	11	418	.075	.98

In Model 2: WK & PC tests make up Verbal factor.
AS, MC, EI, & GS tests make up Technical factor
(GS has a stand. loading of .06 on Technical).
AR & MK tests make up Quantitative factor.

In Model 3: GS, WK, & PC tests make up Verbal factor.
AS, MC, & EI tests make up Technical factor.
AR & MK tests make up Quantitative factor.

In Model 4: GS, WK, & PC tests make up Verbal factor.
AS, MC, EI, AR & GS tests make up Technical factor.
AR & MK tests make up Quantitative factor.

Table 8: Results from Final ASVAB Model (8 Variables)

Includes General Intelligence,
Technical, Verbal, and Quantitative Factors

Goodness of Fit Test:

Chi-square = 418.19, df = 11, $p < .00$

RMSEA = .075, p-value for RMSEA < 0.05 = .00

Fit Indices: GFI = .98, AGFI = .95, NFI = .98, NNFI = .94, CFI = .98

T-values for factor variances:

General = 20.36
Verbal = 8.00
Technical = 17.32
Quantitative = 24.15

Standardized estimates:

	General	Verbal	Technical	Quantitative	Unique Variance
GS	0.67	0.25	0.16		0.46
AR	0.57		0.13	0.53	0.38
WK	0.51	0.78			0.13
PC	0.42	0.28			0.75
AS	0.33		0.87		0.14
MK	0.55			0.54	0.41
MC	0.65		0.40		0.41
EI	0.59		0.45		0.45

Table 9: Correlations between APT Factors and ASVAB Factors

(10 Variables for ASVAB)

	APT Gen	APT Spat	APT FactLrn	APT Induc	ASVAB Gen	ASVAB Verb	ASVAB Tech	ASVAB Quant	ASVAB Speed
APT									
General	1.00								
Spatial	0.00	1.00							
Fact Learn	0.00	0.00	1.00						
Induction	0.00	0.00	0.00	1.00					
ASVAB									
General	0.55	0.40	-0.11	0.38	1.00				
Verbal	0.06	-0.38	0.16	0.09	0.00	1.00			
Technical	-0.01	0.09	-0.09	0.06	0.00	0.00	1.00		
Quantitative	0.47	-0.27	0.07	0.14	0.00	0.00	0.00	1.00	
Speed	0.24	-0.12	-0.11	-0.10	0.00	0.00	0.00	0.00	1.00

Correlations between
APT Factors and ASVAB Factors
(8 Variables for ASVAB)

	APT Gen	APT Spat	APT FactLrn	APT Induc	ASVAB Gen	ASVAB Verb	ASVAB Tech	ASVAB Quant
APT								
General	1.00							
Spatial	0.00	1.00						
Fact Learn	0.00	0.00	1.00					
Induction	0.00	0.00	0.00	1.00				
ASVAB								
General	0.55	0.37	-0.09	0.38	1.00			
Verbal	0.07	-0.35	0.13	0.07	0.00	1.00		
Technical	-0.02	0.15	-0.11	0.08	0.00	0.00	1.00	
Quantitative	0.55	-0.29	0.00	0.07	0.00	0.00	0.00	1.00

Table 10: ASVAB and APT Batteries--10 ASVAB Tests

Note: includes NO & CS

Model	Fit Statistics Degrees of Freedom	Chi-Square	RMSEA	GFI
1) General (G)	209	15382	.105	.78
2) G + Verbal, Spatial, Speed, Technical, Quant, & Fact Learning	192	4967	.061	.93
3) G + Verbal, Spatial, Speed, Technical, Quant, Fact Learning, & Induction	191	4959	.061	.93
4) G + Gc, Gv, Speed, Technical, Quant, & Fact Learning	171	1748	.037	.98

In Model 2: GS, WK, & PC tests make up Verbal.
FLS, SLS, INS, & WMS make up Spatial.
NO & CS make up Speed.
AS, MC, & EI tests make up Technical.
AR, NO, & MK tests make up Quantitative.
FLQ, FLS, & FLV make up Fact Learning.

In Model 3: INQ, INS & INV make up Induction (In).
Loadings for In all fixed to 1 so model will converge.

In Model 4: Model does not have Induction.
Verbal becomes Crystallized Intelligence (Gc).
It is made up of all ASVAB except NO & CS
as well as INV and FLV from the APT Battery.
Spatial becomes Broad Visual Perception (Gv).
It is made up of FLS, SLS, INS, and FLS from APT
as well as AS, MC, EI, GS, and AR from ASVAB.
Add PC, AR, MK to Speed.
Add GS & AR to Technical.
Add INQ and FLQ to Quantitative.

Table 11: Results from Final APT and ASVAB Model (22 Variables)

Includes General Intelligence,
Crystallized Intelligence, Broad Visual Perception,
Speed, Technical, Quantitative, and Fact Learning Factors

Goodness of Fit Test:

Chi-square = 1748.50, df = 172, $p < .00$

RMSEA = .037, p-value for RMSEA < 0.05 = 1.00

Fit Indices: GFI = .98, AGFI = .96, NFI = .96, NNFI = .95, CFI = .96

T-values for the Factor Variances:

General = 25.12
Gc = 23.91
Gv = 13.67
Speed = 24.53
Technical = 19.55
Quantitative = 12. 63
Fact Learning = 5.23

Standardized estimates:

	General	Gc	Gv	Speed	Tech	Quant	Fact Learn	Unique Var
GS	0.35	0.65	0.15		0.14			0.42
AR	0.60	0.21	0.09	0.08	0.20	0.44		0.35
WK	0.28	0.70		0.04				0.43
PC	0.29	0.46		0.12				0.69
NO	0.14			0.55		0.27		0.60
CS	0.18			0.98				0.00
AS	0.12	0.32	0.28		0.68			0.34
MK	0.58	0.19		0.08		0.42		0.44
MC	0.41	0.33	0.43		0.43			0.36
EI	0.23	0.46	0.28		0.49			0.42
WMQ	0.51							0.74
WMS	0.62		0.33					0.50
WMV	0.54							0.71
SLQ	0.60							0.64
SLS	0.54		0.27					0.64
SLV	0.53							0.72
INQ	0.46					0.21		0.74
INS	0.49		0.23					0.71
INV	0.45	0.30						0.71
FLQ	0.38					0.11	0.31	0.75
FLS	0.57		0.47				0.25	0.39
FLV	0.40	0.09					0.31	0.74

Table 12: ASVAB and APT Batteries--8 ASVAB Tests

Note: does not include NO & CS

Model	Fit Statistics Degrees of Freedom	Chi-Square	RMSEA	GFI
1) General (G)	170	11877	.102	.80
2) G + Verbal, Spatial, Speed, Technical, Quant, & Fact Learning	156	4290	.063	.94
3) G + Verbal, Spatial, Speed, Technical, Quant, Fact Learning, & Induction	155	4283	.063	.94
4) G + Gc, Gv, Speed, Technical, Quant, & Fact Learning	139	1400	.037	.98

In Model 2: GS, WK, & PC tests make up Verbal.
FLS, SLS, INS, & WMS make up Spatial.
AS, MC, & EI tests make up Technical.
AR & MK tests make up Quantitative.
FLQ, FLS, & FLV make up Fact Learning.

In Model 3: INQ, INS & INV make up Induction,
loadings all fixed to 1 so model will converge.

In Model 4: Model does not have Induction.
Verbal becomes Crystallized Intelligence (Gc).
It is made up of all ASVAB except NO & CS
as well as INV and FLV from the APT Battery.
Spatial becomes Broad Visual Perception (Gv).
It is made up of FLS, SLS, INS, and FLS from APT
as well as AS, MC, EI, GS, and AR from ASVAB.
Add GS & AR to Technical.
Add INQ and FLQ to Quantitative.

Table 13: Results from Final APT and ASVAB Model (20 Variables)

Includes General Intelligence,
Crystallized Intelligence, Broad Visual Perception,
Technical, Quantitative, and Fact Learning Factors

Goodness of Fit Test:

Chi-square = 1400.20, df = 139, $p < .00$

RMSEA = .037, p-value for RMSEA < 0.05 = 1.00

Fit Indices: GFI = .98, AGFI = .97, NFI = .96, NNFI = .96, CFI = .97

T-values for the Factor Variances:

General = 25.13
Gc = 25.04
Gv = 13.71
Technical = 20.22
Quantitative = 8.71
Fact Learning = 5.24

Standardized estimates:

	General	Gc	Gv	Tech	Quant	Fact Learn	Unique Var
GS	0.35	0.64	0.16	0.16			0.42
AR	0.60	0.19	0.07	0.19	0.48		0.32
WK	0.28	0.71					0.42
PC	0.29	0.45					0.71
AS	0.13	0.30	0.28	0.69			0.34
MK	0.59	0.18			0.40		0.46
MC	0.42	0.31	0.42	0.44			0.36
EI	0.23	0.45	0.28	0.50			0.42
WMQ	0.51						0.74
WMS	0.62		0.33				0.50
WMV	0.54						0.71
SLQ	0.60						0.64
SLS	0.54		0.26				0.64
SLV	0.53						0.72
INQ	0.46				0.21		0.74
INS	0.49		0.22				0.71
INV	0.45	0.30					0.71
FLQ	0.37				0.10	0.31	0.76
FLS	0.57		0.48			0.25	0.38
FLV	0.40	0.08				0.31	0.74

Appendix A: Selected Analyses with Data Corrected for Range Restriction

Table A1
APT Battery Structure

Model	Fit Statistics			
	Degrees of Freedom	Chi-Square	RMSEA	GFI
1) General (G)	54	1042	.053	.97
2) G + Spat, FL, & In	44	368	.033	.99

Table A2
ASVAB Battery
10 Subtests (include NO & CS)

Model	Fit Statistics			
	Degrees of Freedom	Chi-Square	RMSEA	GFI
1) General (G)	35	9083	.198	.75
2) G + Verbal, Technical, Quant, and Speed	25	1483	.094	.96
3) G + Verbal, Technical, Quant, and modified Speed	21	942	.081	.97
4) G + Verbal, Technical, Quant, and modified Speed	20	880	.081	.98
5) G + Verbal, modified Tech, Quant, and modified Speed	18	705	.076	.98

In Model 2: GS, WK, & PC tests make up Verbal factor.
AS, MC, & EI tests make up Technical factor.
AR, NO, & MK tests make up Quantitative factor.
NO & CS make up Speed factor.

In Model 3: add PC, AR, & MK to Speed.

In Model 4: add WK to Speed.

In Model 5: add GS and AR to Technical.

Table A3
Correlations between
APT Nested Factors and ASVAB Nested Factors
corrected for range restriction

	APT				ASVAB				
	Gen	Spat	FactLrn	Induc	Gen	Verb	Quant	Speed	Tech
APT									
General	1.00								
Induction	0.00	1.00							
Spatial	0.00	0.00	1.00						
Fact Learn	0.00	0.00	0.00	1.00					
ASVAB									
General	0.57	0.06	0.07	0.40	1.00				
Verbal	0.16	-0.35	0.04	0.01	0.00	1.00			
Technical	0.04	0.34	-0.26	0.05	0.00	0.00	1.00		
Quantitative	0.56	0.14	-0.11	0.09	0.00	0.00	0.00	1.00	
Speed	0.24	-0.19	-0.11	-0.11	0.00	0.00	0.00	0.00	1.00

Table A4
ASVAB and APT Batteries
10 ASVAB Tests (includes NO & CS)

Model	Fit Statistics Degrees of Freedom	Chi-Square	RMSEA	GFI
1) General (G)	209	15382	.105	.78
2) G + Verbal, Spatial, Speed, Technical, Quant, & Fact Learning	185	4310	.058	.94
3) G + Verbal, Spatial, Speed, Technical, Quant, Fact Learning, & Induction	184	4305	.058	.94
4) G + Gc, Gv, Speed, Technical, Quant, & Fact Learning	171	1826	.038	.97

In Model 2: GS, WK, & PC tests make up Verbal.
FLS, SLS, INS, & WMS make up Spatial.
NO, CS, AR, WK, PC, & MK make up Speed.
AS, MC, EI, GS, & AR tests make up Technical.
AR, NO, & MK tests make up Quantitative.
FLQ, FLS, & FLV make up Fact Learning.

In Model 3: INQ, INS & INV make up Induction (In),
loadings for In all fixed to 1 so model will converge.

In Model 4: Model does not have Induction.
Verbal becomes Crystallized Intelligence (Gc).
It is made up of all ASVAB except NO & CS
as well as INV and FLV from the APT Battery.
Spatial becomes Broad Visual Perception (Gv).
It is made up of FLS, SLS, INS, and FLS from APT
as well as AS, MC, EI, GS, and AR from ASVAB.
Add INQ and FLQ to Quantitative.

Appendix B: Descriptions of the APT Tests

Working Memory:

Quantitative (WMQ) *10 minus n* :
Subjects must remember the last three digits of a three to six digit string. Each digit is presented on a separate screen. If the digit is white, the subject remembers that number. If it is red, the subject must remember ten minus that number.

Spatial (WMS) *Synthesis +/-* :
Subjects were shown two successive screens with matrices of dots, some of which were connected by lines. Then the subject was asked to add or subtract the two and responded by connecting the appropriate dots in a new matrix.

Verbal (WMV) *Furniture-animals order* :
Subjects processed three successively presented screens with sentences that constrained the order of a set of four items. This study used a set of items containing two animals and two pieces offurniture. In one sentence the order for the animals is given, in another the pieces of furniture are grouped, and the third gives the order for the two groups (animals and furniture).

Inductive Reasoning:

Quantitative (INQ) *Number matrices*:
Subjects were shown a 3x3 matrix of numbers with one missing number. Subjects had to figure out the rules governing the series of numbers and fill in the missing space.

Spatial (INS) *Figure series*:
A series of three figures was presented and subjects had to identify the next figure in that series.

Verbal (INV) *Word sets*:
Subjects are shown three sets of words, names, or phrases and must identify the one set that does not belong with the other two sets.

Fact Learning:

Quantitative (FLQ) *2-digit blocks*:
A block of numbers was presented to subjects in one screen. On the next screen, subjects were asked if a number was on the previous list.

Spatial (FLS) *Palmer-Fig Pairs*:
Two figures are presented separately on a 3x3 grid of dots. Subjects are then shown one of the figures and are asked to remember the other one.

Verbal (FLV) *Noun-Pair Lookup*:
Subjects are shown 8 pairs of words to memorize. Then a pair of words is presented and the subject must decide if the pair is in the list. Practice was given with the list displayed at the top of the screen. Then items are given without the prompt list.

Descriptions of the APT Tests
(continued)

Skill Learning:

Quantitative (SLQ) *Odd-Big*:
Subjects memorize a set of rules governing responses. A number is presented and the subject must decide if it is odd or even and if it is big or little. Then the subject uses the rules to respond.

Spatial (SLS) *4-square*:
A 2x2 grid of blocks is displayed and series of four dots is displayed, one in each block, to trace out one of three patterns. The subject must learn the patterns and then identify the pattern when series are presented where either the second or third dot fails to light up.

Verbal (SLV) *Future-Past-Present*:
Two words appear on the screen. Subject must determine if they represent the same or different time periods. Then the subject is presented with words in the 3 different time periods. If the original pair are from the same time, the subject should pick the same time. If they are different, he should pick the word representing the third time period.

Appendix C: Descriptions of the ASVAB Tests

General Science. This test contains 35 standard vocabulary items, such as "Which of the following foods contain the most iron? (a) eggs (b) liver (c) candy (d) cucumber."

Arithmetic Reasoning. This test consists of 30 arithmetic word problems.

Word Knowledge. This test consists of 35 standard vocabulary items, such as "The wind is variable today. (a) mild (b) steady (c) shifting (d) chilling."

Paragraph Comprehension. This test presents 15 paragraphs, each 1-3 sentences long, followed by a multiple-choice response question about the paragraph's content.

Numerical Operations. A 10-minute, speeded test, this consists of 50 number-fact items (e.g., 2X6=? (a) 4 (b) 8 (c) 3 (d) 12.

Coding Speed. A 10-minute, speeded test, this consists of 84 items designed to measure how quickly one can find a number in a table.

Auto and Shop Information (Autoshop). This test consists of 25 questions about automobiles, shop practices, and the use of tools.

Mathematics Knowledge. This test consists of 25 arithmetic word problems (primarily algebra, but also simple geometry.

Mechanical Comprehension. This test consists of 25 questions, normally accompanied by drawings, relating to general mechanical and physical principles.

Electrical Information. This test consists of 20 questions relating to electrical, radio, and electronics information.

Section 2: APT Briefing

ADVANCED PERSONNEL TESTING

Presented To: OASD (FMP) (MPP) AP

15 August 1996

Presented by:

Dr Linda Sawin
Cognitive Technologies Branch
Armstrong Laboratory, Human Resources Directorate

Objective

" To Obtain Approval to Collect Data to Validate the APT Battery across Services

Overview

" Background

" USAF Validation Project

" Interim Results
  - Validity
  - Fairness
  - Classification

" Summary and Recommendation

Background

- Historical Influences
  - Navy - ONR
  - Army - Project A
  - DoD - CAT-ASVAB; ECAT
  - Air Force - LAMP

- Current Battery
  - Theory Driven
  - Computer - Administered

Overview

- Background
- ⇒ USAF Validation Project
- Interim Results
  - Validity
  - Fairness
  - Classification
- Summary and Recommendation

USAF Validation Project

- Purpose: To Examine the Utility of APT Information Processing Battery for Selection and Classification
- 15 Schools plus 2 Core Courses
  - High Flow
  - Range of Job Types and Ability Levels
  - Large Number of Females and Minorities
- Subjects: 15,000-20,000 Airman Basics Tested at Lackland AFB
- 2-5 Years

Career Fields

AFSC	Career Field	Selector AI
1C131Y	Air Traffic Control Operator	G-53
1N335A	Arabic Crypotologic Linguist	G-69
1N431Y	Signals Intelligence Analyst	G-58
2A333B	F-16 Aircraft Maintenance	M-51
2A431Y	Aircraft Guidance and Control	E-67
2A531G	Strategic Aircraft Maintenance (KC-135)	M-51
2A635Y	Aircraft Pneudraulic Systems	M-57
2EO31Y	Ground Radar Systems	E-67
2E131Y	Satellite & Wideband Communications	E-67
2E133Y	Ground Radio Communications	E-67
3A031Y	Information Management	A-32
3C231Y	Communication Computer Systems Control	E-67
3P031Y	Security Police	G-35
3S031Y	Personnel Specialist	A-45
4A031Y	Medical Administrative	G-43
	Fixed Wing Aircraft	M-51
	Electronics Principles	E-67+

Project Status

- Over 9,000 Airman Basics Tested
- Completed Validity Data Collection
  - Security Police
  - Fixed Wing Aircraft Mechanics
  - Electronic Principles
- Completed Equity Data Collection: Security Police

Overview

- Background
- USAF Validation Project
- ⇒ Interim Results
  - Validity
  - Fairness
  - Classification
- Summary and Recommendation

Technical Schools

- Security Police
  - Gen-35
  - N = 1,126
    - ∝ M = 950; F = 176
    - ∝ W = 840; B = 164; Other=122
- Fixed Wing Aircraft
  - Mech-51
  - N = 1,107
    - ∝ M = 1,080; F = 27
    - ∝ W = 930; B = 80; Other=97
- Electronic Principles
  - Elect-67+
  - N = 726
    - ∝ M = 653; F = 73
    - ∝ W = 587; B = 66; Other=73

Goals

- Validity
  - Incremental
  - Simple
  - Constraints on Validity
- Fairness
  - Differential Item Functioning (DIF)
  - Mean Differences
  - Predictive Equity
- Classification Efficiency

Results Overview

- Validity
  - Overall, APT Composites are Incrementally Valid over ASVAB
  - Tests are Valid Predictors of Technical School Performance
- Fairness: APT Exhibits Smaller Sex and Race Differences
- Classification Utility: Shows Promise

Composite Incremental Validity Analyses

- Criterion: Final School Grade
- Predictors: Average of Unit-Weighted Subtests
  - ASVAB-10
  - APT-12
  - APT Process Composites
    - Working Memory (WMS+WMV+WMQ)
    - Fact Learning (FLS+FLV+FLQ)
    - Skill Learning (SLS+SLV+SLQ)
    - Induction (INS+INV+INQ)

APT Composite Incremental Validity Over ASVAB - 10

	APT-12	Fact Learning	Skill Learning	Working Memory	Induction
Security Police G-35 (n = 1,126)	.03	.02	.02	.01	.01
Fixed Wing Aircraft Mechanic M-51 (n = 1,107)	.00	.01	.00	.00	.00
Electronic Principles E-67+ (n = 726)	.08	.06	.07	.04	.02

Change in uncorrected multiple correlation (ΔR)
Composites are unit-weighted and averaged

Table 1

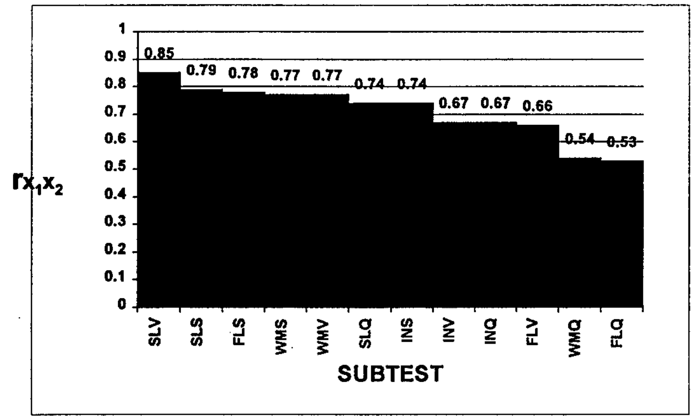
Simple Validity with Final School Grade

	ASVAB - 10	APT - 12
Security Police G-35 (n=1,126)	.39	.32
Fixed Wing Aircraft Mechanic M-51 (n = 1,107)	.46	.28
Electronic Principles E-67+ (n = 726)	.41	.41

Correlations are uncorrected
ASVAB-10 and APT-12 formed by averaging unit-weighted subtests

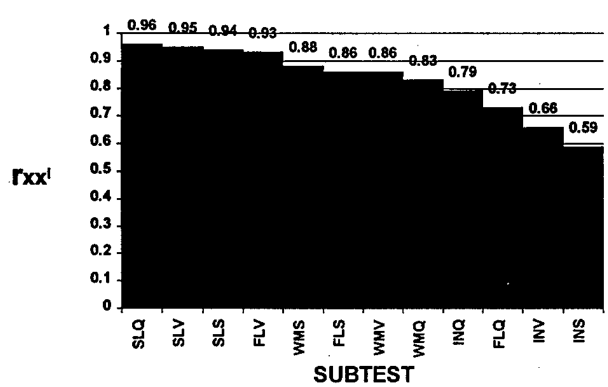
Table 2

Constraints on Validity
Test - Retest



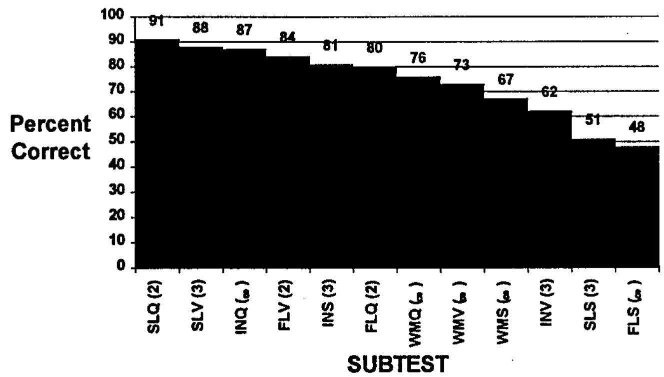
n=300

Constraints on Validity
Internal Consistency



n=6606
Internal consistency measured by Cronbach's Alpha

Constraints on Validity
Subtest Difficulty



n=6606
Difficulty defined as percent correct; number of response options in parentheses

Constraints on Validity
Item Response Theory

- Discrimination (*a*-parameter)
  - Subtests Show Acceptable Discrimination
  - Discrimination Could Be Increased
- Difficulty (*b*-parameter)
  - Overall, Tests are Easy
  - One Test is Difficult: FLS
- Guessing (*c*-parameter)
  - Guessing Correctly Difficult

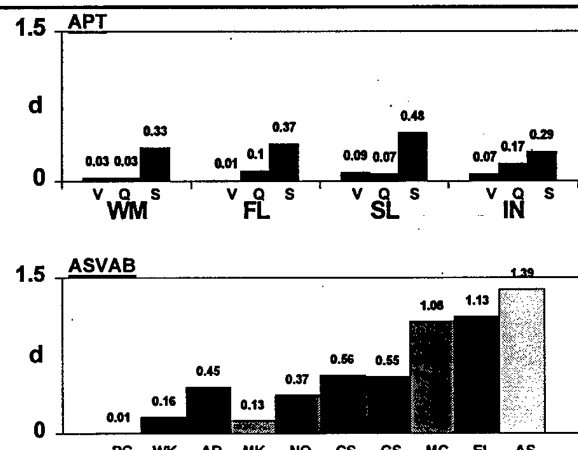
Tables 3-14

Fairness
DIF

- Comparisons
  - Sex
  - Race/Ethnicity
- Results
  - Only Test to Show DIF: Inductive Verbal
  - Differences: Sex

Table 15

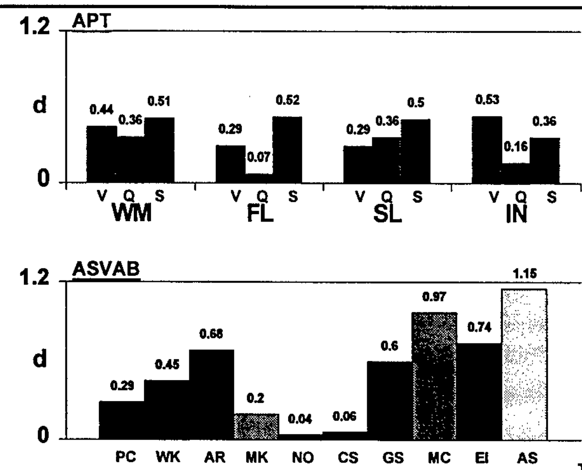
Fairness
Mean Differences - Sex



n=6606

Tables 16 and 17

Fairness
Mean Differences - Race



n=6606

Tables 18 and 19

Fairness
Predictive Equity

- Tested for Differences
  - Standard Errors of Estimate (SEE)
  - Slopes
  - Intercepts
- Results: Security Police
  - No Slope or SEE Differences
  - Overprediction for Females and Blacks

Classification APT and ASVAB Intercorrelations

" APT less Intercorrelated

| Average NORC Corrected Correlations
∝ASVAB-10 = .71
∝ASVAB-8 = .80
(omit NO and CS)
∝APT-12 = .62

" Potential for Greater Classification Efficiency

Correlations corrected for unreliability

Tables 20 and 21

Overview

" Background

" USAF Validation Project

" Interim Results
| Validity
| Fairness
| Classification

⇒ " Summary and Recommendation

Summary

- Validity
  - Demonstrated Incremental Validity
  - Validity Could Be Improved by Increasing:
    - Item Difficulty
    - Item Discrimination
    - Test Reliability
- Fairness
  - Smaller Mean Differences
  - Predictive Equity Similar to ASVAB
- Potential for Classification Efficiency: Less Intercorrelated

Next Steps

- Battery Polishing Underway
  - Construct More Difficult Items
  - Pilot Test More Items on Airman Basics
  - Analyze Results
- Deliver Improved Battery to Other Services

Recommendation

- Direct the Services to collect APT Validity Battery Data

BACKUP SLIDES

APT Process Composites Simple Validity with Final School Grade

	Fact Learning	Skill Learning	Working Memory	Induction
Security Police G-35 (n = 1,126)	.25	.24	.23	.26
Fixed Wing Aircraft Mechanic M-51 (n = 1,107)	.24	.20	.20	.22
Electronic Principles E-67+ (n = 726)	.32	.36	.29	.27

Correlations are uncorrected
Composites are unit-weighted and averaged

Subtest Incremental Validity Analyses

Subtest	Average ΔR	Range
WMQ	.00	.00 - .00
WMS	.01	.00 - .02
WMV	.01	.00 - .02
INQ	.00	.00 - .01
INS	.00	.00 - .00
INV	.00	.00 - .01
FLQ	.01	.01 - .02
FLS	.01	.00 - .01
FLV	.02	.01 - .03
SLQ	.02	.01 - .03
SLS	.01	.00 - .01
SLV	.01	.00 - .02

Average ΔR computed across the three schools

APT Composite Incremental Validity Over AFQT

	APT-12	Fact Learning	Skill Learning	Working Memory	Induction
Security Police G-35 (n = 1,126)	.020	.016	.011	.008	.007
Fixed Wing Aircraft Mechanic M-51 (n = 1,107)	.006	.012	.000	.002	.002
Electronic Principles E-67+ (n = 726)	.090	.063	.074	.036	.022

Change in uncorrected multiple correlation (ΔR)
Composites are unit-weighted and averaged

DIF Indices

- Mantel - Haenszel Chi-Square
- Mantel - Haenszel Odds Ratio/Delta Difference
- Standardized P-Difference
- Root-Mean-Weighted-Squared-Difference

Personnel

APT Scientists
- Jim Earles
- Brad Tiegs
- Meredith Sterling
- Linda Sawin

APT Support
- Mary Becerra
- Terrilee Perdue
- Joanne Hall
- Wayne Crone

AL/HRM
- Melody Darby
- Malcolm Ree
- Lonnie Valentine
- Jacobina Skinner
- Ginger Goff

External Scientists
- Fritz Drasgow
  - University of Illinois
- Mary Roznowski
  - Ohio State University
- Cynthia Searcy
  - University of Georgia

External Advisors
- Paul Sacket
  - University of Minnesota
- Susan Embretson
  - University of Kansas
- Isaac Bejar
  - ETS
- Clint Walker
  - ARI
- David Alderton
  - NPRDC (currently CDC)

Cost-Benefit Analysis

" Annual Savings to Air Force from:
- Better Selection: $1,036,400
- Better Job Performance: $1,619,000
- Total Savings: $2,655,400

" Annual Savings Extrapolated to DoD: $14,752,200

" Net Annual Savings Zero when Cost of Administering APT reaches $88 per Selectee
(Current Cost of ASVAB - $129/Selectee)

Section 3: EQS Model results using full-sample correlations corrected for range restriction

```
/TITLE                                SAMPLE 1
/SPECIFICATIONS
 VARIABLES=22; CASES=9325;  METHODS=ML;
 MATRIX=CORRELATION; ANALYSIS=COVARIANCE;
 fields=6;

/LABELS
V1=GS; V2=AR; V3=WK; V4=PC; V5=NO;
V6=CS; V7=AS; V8=MK; V9=MC; V10=EI;
V11=WMQ4XPCA; V12=WMS3XPCA; V13=WMV1XPCA; V14=SLQ3XPCA; V15=SLS1XPCA;
V16=SLV2XPCA; V17=INQ3XPCA; V18=INS2XPCA; V19=INV1XPCA; V20=FLQ2XPCA;
V21=FLS1XPCA; V22=FLV3XPCA;
F1=general; F2=Gc; F3=Gv; F4=Tech; F5=Quant; F6=FactLrn;  F7=speed;

/technical
iterations=360;

/print
fit=all;

/equations
v1  = *f1  + *f2  + *f3  + *f4                              + e1;
v2  = *f1  + *f2  + *f3  + *f4  + *f5          + *f7      + e2;
v3  = *f1  + *f2                               + *f7      + e3;
v4  = *f1  + *f2                               + *f7      + e4;
v5  = *f1                       + *f5          + *f7      + e5;
v6  = *f1                                      + *f7      + e6;
v7  = *f1  + *f2  + *f3  + *f4                              + e7;
v8  = *f1  + *f2                + *f5          + *f7      + e8;
v9  = *f1  + *f2  + *f3  + *f4                              + e9;
v10 = *f1  + *f2  + *f3  + *f4                              + e10;
v11 = *f1                                                   + e11;
v12 = *f1         + *f3                                     + e12;
v13 = *f1                                                   + e13;
v14 = *f1                                                   + e14;
v15 = *f1         + *f3                                     + e15;
v16 = *f1                                                   + e16;
v17 = *f1                       + *f5                       + e17;
v18 = *f1         + *f3                                     + e18;
v19 = *f1  + *f2                                            + e19;
v20 = *f1                       + *f5 + *f6                 + e20;
v21 = *f1         + *f3               + *f6                 + e21;
v22 = *f1  + *f2                      + *f6                 + e22;
/variances
f1 = 1; f2 = 1; f3 = 1; f4 = 1; f5 = 1; f6 = 1; f7 = 1;
e1=*;
e2=*;
e3=*;
e4=*;
e5=*;
e6=*;
```

```
e7=*;
e8=*;
e9=*;
e10=*;
e11=*;
e12=*;
e13=*;
e14=*;
e15=*;
e16=*;
e17=*;
e18=*;
e19=*;
e20=*;
e21=*;
e22=*;

/covariances  ! could add these; but they are commented out
!F7,F3=*;
!F7,F4=*;
!F6,F3=*;

/matrix
  1.0000
  0.7217   1.0000
  0.8008   0.7079   1.0000
  0.6893   0.6719   0.8027   1.0000
  0.5168   0.6282   0.6047   0.5970   1.0000
  0.4516   0.5140   0.5501   0.5604   0.7025   1.0000
  0.6370   0.5333   0.5291   0.4232   0.2961   0.2250
  0.6947   0.8266   0.6698   0.6370   0.6236   0.5186
  0.6948   0.6843   0.5935   0.5209   0.4037   0.3352
  0.7601   0.6582   0.6839   0.5732   0.4144   0.3416
  0.4403   0.5456   0.4633   0.4415   0.3857   0.3571
  0.4837   0.5819   0.4363   0.4110   0.3561   0.3180
  0.5070   0.5740   0.5529   0.5411   0.4547   0.4381
  0.5063   0.5938   0.5023   0.5055   0.4170   0.3924
  0.4720   0.5835   0.4445   0.4139   0.4159   0.3928
  0.4645   0.5419   0.4917   0.4597   0.3952   0.3622
  0.4604   0.5930   0.4625   0.4453   0.4388   0.3475
  0.4856   0.5478   0.4445   0.4069   0.3441   0.3004
  0.6584   0.6589   0.6929   0.6258   0.4923   0.4414
  0.3125   0.4285   0.3381   0.3469   0.3423   0.3077
  0.4844   0.5439   0.4175   0.3852   0.3003   0.2785
  0.4123   0.4481   0.4310   0.4317   0.3572   0.3604
  1.0000
  0.4152   1.0000
  0.7411   0.6002   1.0000
  0.7454   0.5851   0.7453   1.0000
  0.3019   0.5085   0.4264   0.3775   1.0000
  0.3775   0.5706   0.5350   0.4519   0.4643   1.0000
  0.3326   0.5510   0.4462   0.4252   0.5474   0.5249
  0.3205   0.5914   0.4586   0.4298   0.4494   0.5418
  0.3671   0.5611   0.5385   0.4405   0.4600   0.5340
  0.2883   0.5426   0.4253   0.3969   0.4328   0.4697
  0.3001   0.5833   0.4245   0.3945   0.4120   0.4552
  0.3732   0.5218   0.5148   0.4505   0.4062   0.5067
```

```
  0.4303    0.6336    0.5275    0.5526    0.4400    0.4753
  0.1507    0.4248    0.2551    0.2334    0.3085    0.3992
  0.3899    0.5342    0.5544    0.4575    0.4354    0.6336
  0.2453    0.4540    0.3279    0.3399    0.3691    0.4368
  1.0000
  0.5231    1.0000
  0.4900    0.4805    1.0000
  0.4844    0.5084    0.4513    1.0000
  0.4452    0.4530    0.4290    0.4623    1.0000
  0.4318    0.4607    0.4566    0.4354    0.4417    1.0000
  0.5146    0.5179    0.4470    0.4833    0.4713    0.4695
  0.3622    0.3890    0.3520    0.3529    0.3541    0.3006
  0.4651    0.5034    0.5462    0.4414    0.4144    0.4971
  0.4791    0.4532    0.3928    0.4083    0.3682    0.3532
  1.0000
  0.3707    1.0000
  0.4563    0.3898    1.0000
  0.4397    0.3993    0.4247    1.0000
/standard deviations
 10.0130       10.0126       9.9641       10.0394       9.9586      9.9976
  9.9964        9.9885      10.0434       10.0004      18.5389     25.5200
 25.8858       11.9604      21.8499       17.5959      17.3835     13.8977
 22.8380       10.8668      25.3116        8.4555


/wtest
/lmtest
/end
```

Goff Model fit to corrected correlations for APT and ASVAB test batteries.

```
  GS  .704*F1  +  .497*F2  +  .095*F3  +  .209*F4                                        +  .453 E1
  AR  .822*F1  +  .188*F2  +  .091*F3  +  .131*F4  +  .336*F5              +  .075*F7  +  .382 E2
  WK  .718*F1  +  .587*F2                                                   +  .199*F7  +  .318 E3
  PC  .695*F1  +  .414*F2                                                   +  .246*F7  +  .533 E4
  NO  .607*F1                                      +  .219*F5              +  .588*F7  +  .488 E5
  CS  .564*F1                                                               +  .604*F7  +  .562 E6
  AS  .431*F1  +  .383*F2  +  .302*F3  +  .595*F4                                        +  .472 E7
  MK  .812*F1  +  .141*F2                          +  .357*F5              +  .064*F7  +  .434 E8
  MC  .628*F1  +  .272*F2  +  .378*F3  +  .424*F4                                        +  .457 E9
  EI  .587*F1  +  .457*F2  +  .216*F3  +  .427*F4                                        +  .467 E10
WMQ4  .651*F1                                                                           +  .759 E11
WMS3  .696*F1             +  .341*F3                                                    +  .632 E12
WMV1  .729*F1                                                                           +  .684 E13
SLQ3  .730*F1                                                                           +  .683 E14
SLS1  .665*F1             +  .265*F3                                                    +  .698 E15
SLV2  .677*F1                                                                           +  .736 E16
INQ3  .642*F1                                      +  .188*F5                           +  .743 E17
INS2  .623*F1             +  .234*F3                                                    +  .747 E18
INV1  .716*F1  +  .301*F2                                                               +  .630 E19
FLQ2  .511*F1                                      +  .091*F5  +  .365*F6              +  .773 E20
FLS1  .642*F1             +  .463*F3                           +  .186*F6              +  .582 E21
FLV3  .596*F1  +  .013*F2                                      +  .275*F6              +  .754 E22
```

Fit Statistics:

```
CHI-SQUARE =      3435.267 BASED ON   171 DEGREES OF FREEDOM
BENTLER-BONETT NORMED    FIT INDEX=       0.976
BENTLER-BONETT NONNORMED FIT INDEX=       0.969
COMPARATIVE FIT INDEX (CFI)       =       0.977
BOLLEN (IFI)             FIT INDEX=       0.977
McDonald (MFI)           FIT INDEX=       0.839
LISREL GFI               FIT INDEX=       0.966
LISREL AGFI              FIT INDEX=       0.950
ROOT MEAN SQUARED RESIDUAL (RMR)  =       5.826
STANDARDIZED RMR                  =       0.000
ROOT MEAN SQ. ERROR OF APP.(RMSEA)=       0.045
```

```
/TITLE                                          SAMPLE 2
/SPECIFICATIONS
 VARIABLES=23; CASES=2270;  METHODS=ML;
 MATRIX=CORRELATION; ANALYSIS=COVARIANCE;
 fields=6;
/LABELS
V1=GS; V2=AR; V3=WK; V4=PC; V5=NO;
V6=CS; V7=AS; V8=MK; V9=MC; V10=EI;
V11=WMQ4XPCA; V12=WMS3XPCA; V13=WMV1XPCA; V14=SLQ3XPCA; V15=SLS1XPCA;
V16=SLV2XPCA; V17=INQ3XPCA; V18=INS2XPCA; V19=INV1XPCA; V20=FLQ2XPCA;
V21=FLS1XPCA; V22=FLV3XPCA; V23=CRS_GRD;

/technical
iterations=360;

/print
fit=all;

/equations
v1  = *f1  + *f2  + *f3  + *f4                                + e1;
v2  = *f1  + *f2  + *f3  + *f4  + *f5            + *f7        + e2;
v3  = *f1  + *f2                                 + *f7        + e3;
v4  = *f1  + *f2                                 + *f7        + e4;
v5  = *f1                       + *f5            + *f7        + e5;
v6  = *f1                                        + *f7        + e6;
v7  = *f1  + *f2  + *f3  + *f4                                + e7;
v8  = *f1  + *f2                + *f5            + *f7        + e8;
v9  = *f1  + *f2  + *f3  + *f4                                + e9;
v10 = *f1  + *f2  + *f3  + *f4                                + e10;
v11 = *f1                                                     + e11;
v12 = *f1         + *f3                                       + e12;
v13 = *f1                                                     + e13;
v14 = *f1                                                     + e14;
v15 = *f1         + *f3                                       + e15;
v16 = *f1                                                     + e16;
v17 = *f1                       + *f5                         + e17;
v18 = *f1         + *f3                                       + e18;
v19 = *f1  + *f2                                              + e19;
v20 = *f1                       + *f5     + *f6               + e20;
v21 = *f1         + *f3                   + *f6               + e21;
v22 = *f1  + *f2                          + *f6               + e22;
v23 = *f1  + *f2    + *f3  + *f4   + *f5  + *f6  + *f7        + e23;

/variances
f1 = 1; f2 = 1; f3 = 1; f4 = 1; f5 = 1; f6 = 1; f7 = 1;
e1=*;
e2=*;
e3=*;
e4=*;
e5=*;
e6=*;
e7=*;
e8=*;
e9=*;
e10=*;
e11=*;
e12=*;
```

```
e13=*;
e14=*;
e15=*;
e16=*;
e17=*;
e18=*;
e19=*;
e20=*;
e21=*;
e22=*;
e23=*;

/covariances

/matrix
  1.0000
  0.7217   1.0000
  0.8008   0.7079   1.0000
  0.6893   0.6719   0.8027   1.0000
  0.5168   0.6282   0.6047   0.5970   1.0000
  0.4516   0.5140   0.5501   0.5604   0.7025   1.0000
  0.6370   0.5333   0.5291   0.4232   0.2961   0.2250
  0.6947   0.8266   0.6698   0.6370   0.6236   0.5186
  0.6948   0.6843   0.5935   0.5209   0.4037   0.3352
  0.7601   0.6582   0.6839   0.5732   0.4144   0.3416
  0.3588   0.4862   0.3685   0.3603   0.3085   0.2941
  0.4663   0.5567   0.4261   0.3750   0.3182   0.3022
  0.5013   0.5619   0.5505   0.5299   0.4327   0.4293
  0.4700   0.5539   0.4691   0.4743   0.3784   0.3710
  0.4900   0.5906   0.4711   0.4159   0.4118   0.3988
  0.4650   0.5240   0.4827   0.4437   0.3713   0.3476
  0.4668   0.5817   0.4707   0.4171   0.4193   0.3204
  0.4582   0.5168   0.4179   0.3620   0.2886   0.2531
  0.6519   0.6466   0.6853   0.6246   0.4807   0.4280
  0.2838   0.4063   0.3022   0.3220   0.3186   0.2724
  0.4740   0.5251   0.4063   0.3487   0.2798   0.2690
  0.4222   0.4472   0.4322   0.4248   0.3621   0.3795
  0.6639   0.6612   0.6542   0.6244   0.5268   0.4734
  1.0000
  0.4152   1.0000
  0.7411   0.6002   1.0000
  0.7454   0.5851   0.7453   1.0000
  0.2349   0.4488   0.3673   0.3092   1.0000
  0.3642   0.5570   0.5302   0.4360   0.4094   1.0000
  0.3129   0.5288   0.4414   0.4186   0.4965   0.4931
  0.2817   0.5575   0.4151   0.3978   0.3951   0.4935
  0.3896   0.5659   0.5658   0.4710   0.4258   0.5157
  0.2756   0.5230   0.4108   0.3981   0.3639   0.4460
  0.2917   0.5675   0.4109   0.3965   0.3466   0.4311
  0.3406   0.5055   0.4886   0.4337   0.3616   0.5005
  0.4156   0.6230   0.5281   0.5432   0.3747   0.4610
  0.1143   0.4079   0.2355   0.2161   0.2673   0.3657
  0.3674   0.5258   0.5469   0.4543   0.3993   0.6445
  0.2353   0.4550   0.3187   0.3328   0.3151   0.4015
  0.4916   0.6646   0.5500   0.6065   0.3496   0.4654
  1.0000
  0.4961   1.0000
```

```
 0.4917   0.4662   1.0000
 0.4672   0.4878   0.4412   1.0000
 0.4332   0.4084   0.4185   0.4085   1.0000
 0.4053   0.4179   0.4381   0.4155   0.4357   1.0000
 0.5207   0.4942   0.4543   0.4707   0.4641   0.4513
 0.3207   0.3532   0.3304   0.3111   0.3143   0.2754
 0.4591   0.4739   0.5447   0.4434   0.3940   0.4657
 0.4646   0.4261   0.4015   0.3819   0.3602   0.3263
 0.5001   0.4977   0.4552   0.4759   0.4720   0.4064
 1.0000
 0.3547   1.0000
 0.4499   0.3702   1.0000
 0.4533   0.3922   0.4284   1.0000
 0.5691   0.3477   0.4349   0.4524   1.0000
/standard deviations
10.0130 10.0126  9.9641 10.0394  9.9586  9.9976
 9.9964  9.9885 10.0434 10.0004 17.3387 24.3161
25.4225 11.7179 21.7519 17.6412 16.2118 13.5377
22.5809 10.4000 24.9964  8.0408  7.8028


/wtest
/lmtest
/end
```

Goff Model fit to corrected correlations and extended to predict final course grade.

```
GS      .709*F1  +  .490*F2  +  .075*F3  +  .219*F4                                                  +  .450 E1
AR      .814*F1  +  .186*F2  +  .095*F3  +  .133*F4  +  .338*F5                        +  .096*F7  +  .390 E2
WK      .718*F1  +  .579*F2                                                            +  .204*F7  +  .327 E3
PC      .684*F1  +  .428*F2                                                            +  .261*F7  +  .530 E4
NO      .586*F1                                      +  .231*F5                        +  .603*F7  +  .489 E5
CS      .556*F1                                                                        +  .620*F7  +  .554 E6
AS      .417*F1  +  .399*F2  +  .298*F3  +  .607*F4                                                +  .457 E7
MK      .812*F1  +  .131*F2                          +  .367*F5                        +  .082*F7  +  .427 E8
MC      .622*F1  +  .282*F2  +  .395*F3  +  .414*F4                                                +  .454 E9
EI      .591*F1  +  .452*F2  +  .209*F3  +  .429*F4                                                +  .468 E10
WMQ4    .577*F1                                                                                    +  .817 E11
WMS3    .673*F1              +  .373*F3                                                            +  .639 E12
WMV1    .717*F1                                                                                    +  .697 E13
SLQ3    .699*F1                                                                                    +  .715 E14
SLS1    .670*F1              +  .272*F3                                                            +  .691 E15
SLV2    .660*F1                                                                                    +  .751 E16
INQ3    .621*F1                                      +  .196*F5                                    +  .759 E17
INS2    .599*F1              +  .225*F3                                                            +  .768 E18
INV1    .717*F1  +  .288*F2                                                                        +  .634 E19
FLQ2    .474*F1                                      +  .125*F5  +  .342*F6                        +  .801 E20
FLS1    .638*F1              +  .463*F3                          +  .204*F6                        +  .581 E21
FLV3    .592*F1  +  .022*F2                                      +  .339*F6                        +  .731 E22
CRS_GRD .707*F1  +  .224*F2  + -.036*F3  +  .188*F4  +  .081*F5  +  .109*F6  +  .098*F7  +  .621 E23
```

Fit Statistics:

```
CHI-SQUARE =      1109.969 BASED ON   186 DEGREES OF FREEDOM
BENTLER-BONETT NORMED    FIT INDEX=       0.969
BENTLER-BONETT NONNORMED FIT INDEX=       0.965
COMPARATIVE FIT INDEX (CFI)      =       0.974
BOLLEN (IFI)             FIT INDEX=       0.974
McDonald (MFI)           FIT INDEX=       0.816
LISREL GFI               FIT INDEX=       0.958
LISREL AGFI              FIT INDEX=       0.938
ROOT MEAN SQUARED RESIDUAL (RMR)  =       6.284
STANDARDIZED RMR                  =       0.000
ROOT MEAN SQ. ERROR OF APP.(RMSEA)=       0.047
```

Uncorrected correlations and standard deviations: Sample 1 (n=9325)

```
/matrix
 1.00
  .376 1.00
  .544  .284 1.00
  .349  .279  .419 1.00
 -.010  .210 -.019  .088 1.00
 -.018  .161  .040  .137  .555 1.00
  .387  .273  .257  .154 -.115 -.110
  .375  .582  .225  .238  .239  .178
  .474  .456  .345  .248 -.041 -.032
  .504  .347  .375  .240 -.072 -.061
  .156  .325  .154  .144  .082  .101
  .241  .387  .155  .145  .050  .064
  .177  .291  .191  .198  .105  .142
  .217  .350  .162  .194  .084  .111
  .202  .377  .139  .126  .120  .147
  .177  .293  .176  .149  .076  .091
  .169  .371  .126  .134  .137  .086
  .251  .342  .175  .142  .037  .043
  .341  .339  .336  .243  .053  .066
  .075  .242  .066  .100  .123  .117
  .275  .357  .174  .147  .000  .031
  .150  .201  .129  .151  .079  .121
 1.00
  .102 1.00
  .570  .345 1.00
  .589  .257  .569 1.00
  .085  .264  .220  .111 1.00
  .176  .374  .370  .227  .313 1.00
  .083  .260  .199  .115  .387  .369
  .083  .352  .236  .153  .265  .395
  .152  .345  .364  .198  .301  .396
  .055  .301  .211  .126  .257  .313
  .071  .355  .198  .120  .228  .287
  .171  .308  .347  .228  .243  .371
  .151  .310  .257  .223  .193  .264
 -.031  .232  .065  .006  .160  .276
  .201  .351  .415  .256  .291  .538
  .041  .219  .112  .094  .201  .296
 1.00
  .325 1.00
  .311  .306 1.00
  .288  .334  .282 1.00
  .235  .256  .246  .284 1.00
  .246  .293  .302  .273  .276 1.00
  .234  .271  .208  .240  .224  .260
  .200  .242  .213  .207  .206  .160
  .307  .361  .425  .293  .252  .371
  .310  .288  .233  .242  .192  .194
 1.00
  .183 1.00
  .263  .276 1.00
  .220  .281  .294 1.00
```

```
/standard deviations

    6.635     6.560     4.346     4.644     6.022     6.865
    8.246     6.443     8.026     7.727    16.306    22.491
   21.440    10.145    19.071    15.265    14.991    12.352
   17.098    10.062    22.727     7.572
```

```
Uncorrected correlations and standard deviations: Sample 2 (n=2270)

/matrix
 1.000
  .397 1.000
  .556  .300 1.000
  .324  .252  .418 1.000
 -.067  .167 -.058  .025 1.000
 -.091  .109 -.022  .111  .583 1.000
  .421  .302  .293  .171 -.172 -.188
  .357  .562  .200  .202  .227  .149
  .495  .467  .364  .245 -.115 -.123
  .504  .378  .385  .240 -.145 -.146
  .130  .322  .115  .112  .049  .069
  .247  .376  .176  .112 -.001  .022
  .184  .288  .207  .188  .070  .115
  .195  .320  .147  .172  .053  .088
  .222  .383  .173  .109  .077  .105
  .197  .283  .183  .135  .045  .061
  .195  .367  .158  .090  .103  .040
  .259  .339  .190  .113 -.025 -.022
  .348  .332  .342  .243  .017  .019
  .063  .233  .045  .086  .116  .096
  .290  .355  .190  .112 -.034 -.008
  .158  .195  .125  .133  .082  .131
  .342  .334  .259  .243  .082  .081
 1.000
  .077 1.000
  .613  .306 1.000
  .630  .239  .611 1.000
  .061  .249  .198  .101 1.000
  .184  .366  .382  .238  .288 1.000
  .068  .229  .201  .120  .372  .345
  .060  .325  .195  .141  .253  .355
  .184  .332  .395  .245  .294  .380
  .053  .281  .199  .145  .220  .300
  .067  .336  .184  .133  .196  .274
  .169  .311  .346  .253  .240  .388
  .151  .291  .274  .225  .181  .270
 -.061  .235  .052  .008  .153  .254
  .199  .347  .424  .286  .286  .564
  .021  .214  .087  .073  .172  .257
  .257  .353  .278  .326  .135  .262
 1.000
  .313 1.000
  .313  .298 1.000
  .280  .329  .271 1.000
  .235  .223  .234  .228 1.000
```

```
  .242  .271  .296  .273  .292 1.000
  .261  .268  .216  .240  .228  .273
  .171  .223  .198  .177  .177  .155
  .317  .344  .430  .311  .242  .356
  .293  .264  .234  .213  .187  .175
  .220  .264  .199  .240  .229  .196
 1.000
  .188 1.000
  .279  .268 1.000
  .241  .286  .302 1.000
  .244  .171  .242  .233 1.000

/standard deviations
  6.708  6.807  4.464  4.753  5.873  6.821
  8.665  6.338  8.364  8.071 15.980 21.753
 21.278 10.178 18.857 15.470 14.100 12.322
 17.150  9.745 22.753  7.187  5.843
```